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Soybean Aphid and Potato Leafhopper Thresholds: Revisiting IPM Decision Support for Soybeans and Alfalfa in a High Value Field Crop Commodity Rotation

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Soybean aphid and potato leafhopper thresholds: Revisiting IPM decision support for soybeans and alfalfa in a high value field crop commodity rotation

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After attending this workshop, participants will gain knowledge necessary to:

- Define the IPM terms *economic injury level, economic threshold, damage boundary,* and *gain threshold.*
- Answer the question, "do insect economic thresholds change with higher crop prices?"
- Identify the components that make up an insect economic injury level
- Understand why the soybean aphid economic threshold of 250 aphids/plant does not change when soybean prices increase from $5.50/bushel to $15.00/bushel.
- Understand how potato leafhopper economic thresholds in alfalfa may help preserve long-standing biological control success for alfalfa weevil.

Background

The National Research Council (1989) equated integrated pest management (IPM) adoption in field and forage crops with pest scouting and use of economic thresholds before a decision is made to apply insecticide. Three IPM terms and definitions are important for discussion purposes and data review during this workshop presentation.

Economic Injury Level (EIL): The EIL is defined as the lowest number of insects that will cause economic damage (i.e., amount of pest injury justifies cost of insecticide application given control costs and value of the crop (Pedigo 1989).

Economic Threshold (ET): The ET is set below the EIL to allow lead time to arrange insecticide treatment and suppress an insect population before it reaches the EIL (Stern et al. 1959). The ET is based on an understanding of population dynamics and growth rates for the particular insect pest. By setting the ET at a lower value than the EIL, we are predicting that once the population reaches the ET, chances are good that it will grow to exceed the EIL. Economic thresholds are also referred to as "action thresholds" or simply "thresholds". That is, the point at which treatment is recommended to prevent pest populations from reaching the EIL.

Damage Boundary: The number of a pest insect that must be present before its injury can be measured as yield loss (Pedigo 1989). Regardless of crop price, there is no reason to spend money, effort, or environmental impact to control insects that are present in numbers fewer than the damage boundary because there will not be any observable return in protected yield and there can be detrimental effects on natural enemy insects (Tollefson et al. 2008).

Do insect economic thresholds change with higher crop prices?

Keeping in mind that the economic threshold (i.e., the insect population density at which control action is taken) is already set below the economic injury level, the question we really need to be asking is *do insect Economic Injury Levels (EILs) change with higher crop prices?* Yes, the calculation of an EIL for an insect is a continuing process because new values are required with changes in the input variables. Consequently, when crop market value, management costs, and/or plant susceptibility change, recalculation of the EIL is necessary (Pedigo 1989).

How do entomologists determine the economic injury level (EIL)?

In order for entomologists to calculate the EIL, we need to know the straightforward values such as cost of treatment per acre, and value of crop per acre (grain crops) or per ton (alfalfa hay). Looking strictly at the economics of an insect pest management decision, entomologists and IPM practitioners first consider the *gain threshold*. The gain threshold is expressed in amount of harvestable yield; when cost of suppressing insect injury equals money to be gained from avoiding the damage. The gain threshold is expressed as:

$$\textit{Gain threshold} = \frac{\text{Management costs (\$/acre)}}{\text{Market value (\$/bushel)}} = \text{bushels/acre}$$

For example, if management costs for application of an insecticide are $18 per acre and harvested corn is marketed for $5.00 per bushel, the gain threshold would be 3.6 bushels per acre. The gain threshold is an important measure because it represents a basic margin for determining benefits of management and establishing treatment decision parameters (Pedigo 1989). The gain threshold is a basic break-even analysis and can be calculated as a first step when determining the EIL (Pedigo et al. 1986).

However, in order to determine the Economic Injury Level, we need more than the gain threshold, we also need to know how much yield loss the insect pest population causes at various population densities. Farmers and consultants need reliable information on the statistical relationship between insect pest population levels and crop yield loss, an estimate of yield loss per insect.

To estimate the damage per insect, research plots are set up with various-sized insect populations on a crop at specific growth stages. Depending on the crop and insect pest combination, and on how the study is designed, various-sized insect population treatments may be established by infesting plots or caged plants with specific numbers of the pest insect, or by manipulating insect population levels using different rates and timing of insecticide application. Subsequently, yields are measured at the end of the season for grain crops, or at cutting for alfalfa harvest, and statistical procedures are used to determine the loss per insect. Entomologists use linear regression analysis, a statistical procedure, to analyze field research data and determine the relationship between number of insects per plant and yield loss.

We need this information over a wide range of insect pest densities, even very low levels of insect pest populations. It's actually very useful for farmers and IPM consultants to know with a high level of certainty that insect pest densities below a certain level will not cause measurable yield loss in experiments. In other words, at a certain point insect numbers are low enough that there is no yield difference between treated and untreated plots. Regardless of how high crop prices go, there is no benefit or need to treat below the *damage boundary*. Conversely, as long as the insect population is above the damage boundary, increasing crop prices may lead to a decrease in the EIL. Under these conditions, a lower insect pest population causes injury that justifies insecticide application given the higher value of the crop.

The full EIL equation incorporates cost of treatment per acre (C), value of the crop (V), yield potential of the crop (Yp), statistical coefficients from the linear regression relationship between insects per plant and yield loss (a and b), and the proportion of control that can be achieved by treatment (K). However, the basic formula for calculating the EIL can be condensed as written below (Pedigo 1989). The take-home message is that the EIL includes more than just the cost of treatment per acre and market value of the crop.

$$\text{EIL} = \frac{\text{gain threshold}}{\text{loss per insect}}$$

For insect pest/crop combinations when the relationship between insects per plant and yield loss cannot be approximated by a straight line (i.e., it is curvilinear), a more complex form of the EIL equation must be used.

Revisiting IPM decision support for field and forage crop insect pests

North Central region field and forage crops are intimately linked as alfalfa is the primary perennial legume crop in rotation with annual commodity crops. This agricultural system is undergoing rapid change in terms of increasing crop prices, and the proportion of acreage planted to each of these crops. In Wisconsin, for example, a significant shift occurred in 2007 when farmers planted 4.1 million acres of corn – 11% more than in 2006. Many of these corn acres came from soybean acres. In 2008, soybeans returned to average state level (1.7 million acres), while winter wheat increased to 350,000 acres (a 40% increase from 2006). By contrast, Wisconsin alfalfa remained constant at 2.4 million acres from 2003 to 2008 and new seedings decreased by 26% from 500,000 acres in 2007 to 370,000 acres in 2008 (data: USDA NASS 2008). Corn and soybean crop prices have increased significantly and remained favorable over the last two to three years, due in part to surging investment in biofuels. In 2007, alfalfa prices increased sharply, partly due to tight hay supplies and partly in response to rapid increase in corn costs exerting upward pressure on forage value (Mintert 2008).

Farmers and consultants are questioning whether to lower economic thresholds (ET) and apply insecticide at lower insect pest densities in field and forage crop systems. The EIL and ET levels for soybean aphid, *Aphis glycines* Matsumura, were developed quite recently and published in 2007 (Ragsdale et al. 2007). By comparison, EIL and ET levels for potato leafhopper, *Empoasca fabae* (Harris), in alfalfa were first developed over 20 years ago (Cuperus et al. 1983). Although potato leafhopper (PLH) economic thresholds have been revisited for PLH-resistant glandular haired alfalfa varieties (Lefko et al. 2000), hay and forage producers ask frequently if they should treat below established economic thresholds on PLH-susceptible (normal) alfalfa varieties, given increasing alfalfa hay prices (Holin 2008).

This workshop will explore two case studies. First, we review the recent North Central region university research data (Ragsdale et al. 2007) for soybean aphid yield-loss measurements across six states over three years, and a wide range of soybean prices, including recent high prices in the 'teens'. Second, we review existing yield-loss relationship data for potato leafhopper in alfalfa and the link between leafhopper insecticide application timing and parasitoids responsible for alfalfa weevil biological control.

Case study 1: Soybean aphid economic threshold

A common question during the 2008 growing season was ... "The price of beans needs to be factored into the threshold in some way. Do $15 soybeans mean we lower the economic threshold below 250 aphids/plant?".

The economic threshold of 250 aphids/plant has not changed.

The soybean aphid economic threshold is valid through the R5 stage. Replicated field plot research was conducted over 3 years, in 19 yield-loss experiments, across 6 states (Iowa, Michigan, Minnesota, Nebraska, North Dakota, and Wisconsin). This data set was used to determine the relationship between number of aphids/plant and yield loss across a range of aphid densities and soybean varieties.

The economic threshold (ET) of 250 aphids/plant is set below the economic injury level (EIL). When the research was conducted 2004, 2005, 2006, soybean prices were $5.50-$6.50/bushel. At that time the EIL, or number of aphids that need to be present for the value of the lost yield to equal the costs of control, was approximately 674 aphids/plant.

Now that market value for soybeans has increased, a lower EIL can be calculated (based on the linear regression analysis of the relationship between soybean aphid/plant and soybean yield over a wide range of densities, over three years across 6 states). David Ragsdale, the lead author of the Economic Threshold study (Journal of Economic Entomology 100: 1258-1267) re-calculated the EIL. For example, for soybeans selling at $15/bushel, with $8/acre control costs, and anticipated yield of 50 bu/acre. The EIL is lowered from 674 aphids/plant to 450 aphids/plant.

The economic threshold (i.e., insect population density at which control action is taken) of 250 aphids/plant is still below this revised EIL of 450 aphids per plant. When soybean prices were $5.50-$6.50/bushel, the ET of 250 aphids/plant allowed 7 days lead time to treat before reaching the EIL of 674 aphid/plant. A lower EIL (450 aphids/plant) given higher soybean prices, simply reduces the lead time to 3-4 days to treat before reaching the EIL. Thus, the economic threshold of 250 aphids/plant has not changed.

For an excellent, detailed explanation of the Upper Midwest research data behind the soybean aphid economic threshold of 250 aphids/plant and Economic Injury Level, please see the Plant Management Network web seminar with voice narration. It takes about 26 minutes to view the slide set. Access the presentation by Dr. Dave Ragsdale, University of Minnesota, at: http://www.plantmanagementnetwork.org/edcenter/seminars/SoybeanAphid/

From the link above, click on "Part II: Soybean Aphid: Economic Threshold and Economic Injury Level".

In our research across the Upper Midwest, using the common experimental protocol detailed in the web seminar above, treating below 250 aphids/plant resulted in NO detectable yield increase. 250 aphids/plant is not where injury begins, it is below the *damage boundary*. The economic threshold of 250 aphids/plant provides lead time to treat the field within a few days to prevent it from reaching the revised EIL of 450 aphids/plant.

Case study 2: Potato leafhopper economic thresholds

Initial research that established an economic injury level and economic thresholds for potato leafhopper on alfalfa was conducted between 1979-1981 in Minnesota (Cuperus et al. 1983). This research was performed on established alfalfa stands in 0.25 acre plots. Rather than infesting plots, or caging plants within plots, natural infestation potato leafhopper population densities were manipulated across treatments by cutting practices (maintaining uncut alfalfa refuges from which potato leafhoppers could infest treatment plots) and application of insecticides. Potato leafhoppers were sampled weekly during 2^{nd} and 3^{rd} crops, at various crop heights ranging from 2 to 21 inches. Similar to soybean aphid EIL studies (Ragsdale et al. 2007), potato leafhopper abundance was expressed as potato leafhopper/sweep/week. Cumulative numbers are used because damage potential depends on duration of infestation, population density, and alfalfa height when infestation occurs.

In this original work (Cuperus et al. 1983), the potato leafhopper EIL was defined as the number of cumulative potato leafhopper/sweep/week that caused a yield loss reduction equivalent in value to the cost of control. The study used a control cost of $6.50 per acre application cost of dimethoate, and 1983 alfalfa crop values calculated based on cost of replacement feeds (soybean meal; corn) at the time. In summary, this original work established an economic injury level of approximately 0.74 potato leafhoppers (PLH) per sweep; and economic thresholds for a range of alfalfa heights: 0.32 PLH/sweep at 2 inches, 0.40 PLH/sweep at 5 inches, and 0.5 PLH/sweep at 7 inches.

Compared to the research data set for soybean aphid economic injury levels and economic threshold where the damage boundary is known (Ragsdale et al. 2007), potato leafhopper studies have not yet identified the damage boundary on alfalfa. Cuperas et al. (1983) did show that alfalfa dry-matter yield loss per potato leafhopper is a curvilinear relationship, with more yield loss at low leafhopper numbers than at high leafhopper numbers. However, their economic injury level and economic thresholds summarized above took this relationship into account. Moreover, the potato leafhopper economic thresholds in use today for non-glandular haired varieties (DeGooyer et al. 1998; Lefko et al. 2000) are more conservative than those originally calculated by Cuperas et al. (1983).

Current potato leafhopper economic thresholds on alfalfa are 0.1 potato leafhopper (nymphs and/or adults) per 15 inch diameter sweep net sample for each 1 inch of plant height, if the alfalfa is < 10 inches tall, and ≥ 2 potato leafhoppers per sweep if the alfalfa is taller than 10 inches (DeGooyer et al. 1998, Rice 1996, Boerboom et al. 2008). For example, the economic threshold for 6 inch alfalfa is reached at 5 potato leafhoppers/10 sweeps, or 0.5/sweep. Taller plants are able to tolerate more leafhoppers (Wilson et al. 1989). If the economic threshold is reached on tall alfalfa within 7 days of planned harvest, the cultural control of early harvest is advised, rather than insecticide treatment (Undersander et al. 2004).

Finally, alfalfa supports a diverse population of insect species. In addition to potato leafhopper, key insect pests in Wisconsin and the North Central region include alfalfa weevil, *Hypera postica* (Gyllenhal), and a complex of aphid species dominated by pea aphid, *Acyrthosiphon pisum* (Harris). The rest are local, sporadic or incidental herbivores, and many are beneficial insect predators and parasitoids, or pollinators (Flanders and Radcliffe 2000). A highly successful importation biological control project for alfalfa weevil in the Midwest established multiple parasitoid species that have nearly eliminated the need for insecticide application against alfalfa weevil (Radcliffe and Flanders 1998). Moreover, alfalfa provides an ecosystem service (Koshel and Mcallister 2008) as habitat for beneficial insects important to annual crop/pest combinations such as soybean/soybean aphid (Schmidt et al. 2007).

Potato leafhopper represents the pivotal insecticide use decision for Wisconsin farmers each year in alfalfa, a crop with several attributes, as described above, which make it an excellent candidate for the application of IPM approaches.

Current potato leafhopper economic thresholds appear conservative enough to protect against dry-matter yield loss in the current high value hay market. At this time, university research does not support lowering potato leafhopper economic thresholds below the current 0.1 PLH/sweep for each 1 inch of plant height. Additional field research quantifying "no effect" (i.e., damage boundary) when alfalfa is treated below current economic thresholds would be useful and preliminary studies in Wisconsin aim to obtain these data.

This workshop will conclude with a discussion of how current economic threshold treatment decision support for potato leafhopper in alfalfa will continue to provide IPM decision support allowing growers and advisors to benefit from highly effective potato leafhopper insecticide management tactics, while re-focusing on the importance of scouting-based economic threshold treatment decisions to preserve long-standing biological control success for alfalfa weevil.

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